A Vision for the Future of Highway Projects – Substantive Safety and Project Development

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NCHRP Project 15-47 Introduction

During the past 60 years, transportation needs have changed and much has been learned about the relationships among geometric design, vehicle fleet, human factors, safety, and operations. AASHTO has continually updated its policies to respond to these changes, but such updates have provided limited changes to the fundamental process or basic design approaches…..

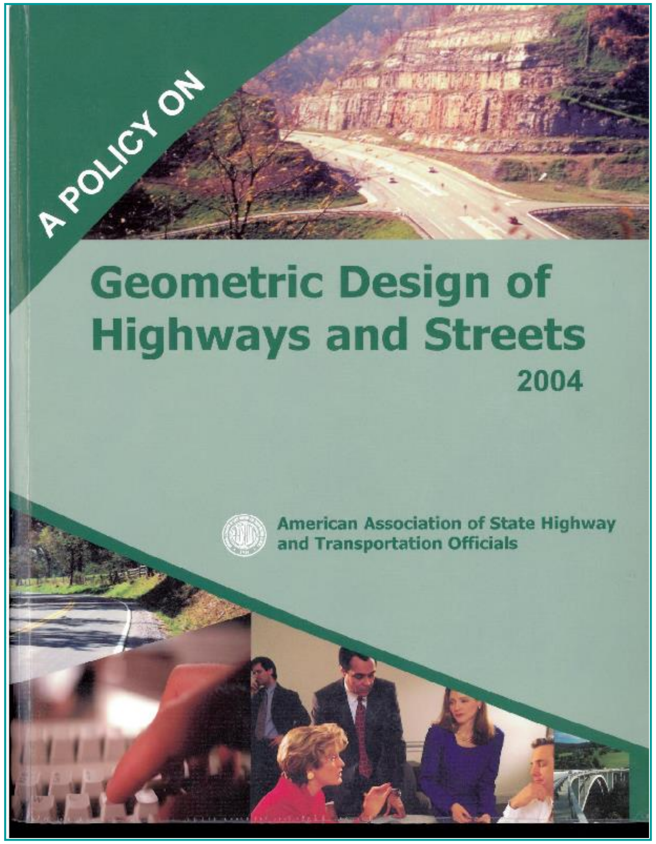
An assessment of the current design process is needed to ensure that recent advances in knowledge (e.g., the AASHTO *Highway Safety Manual*) and emerging issues (e.g., complete streets, flexible design) are appropriately addressed.

Background (per CH2M's research efforts)

The recommended geometric design process reflects an understanding of:

- The history of highway design
- The growth in knowledge of design effects on roadway performance
- The changes in emphasis and importance of road design and road users over the years
- The legal framework that shapes implementation and management of public infrastructure
- The advances in technology that facilitate roadway design
- The growing and seemingly permanent condition of limited resources for construction, operation, and maintenance of roads in the United States.

Evolution of the AASHTO Green Book



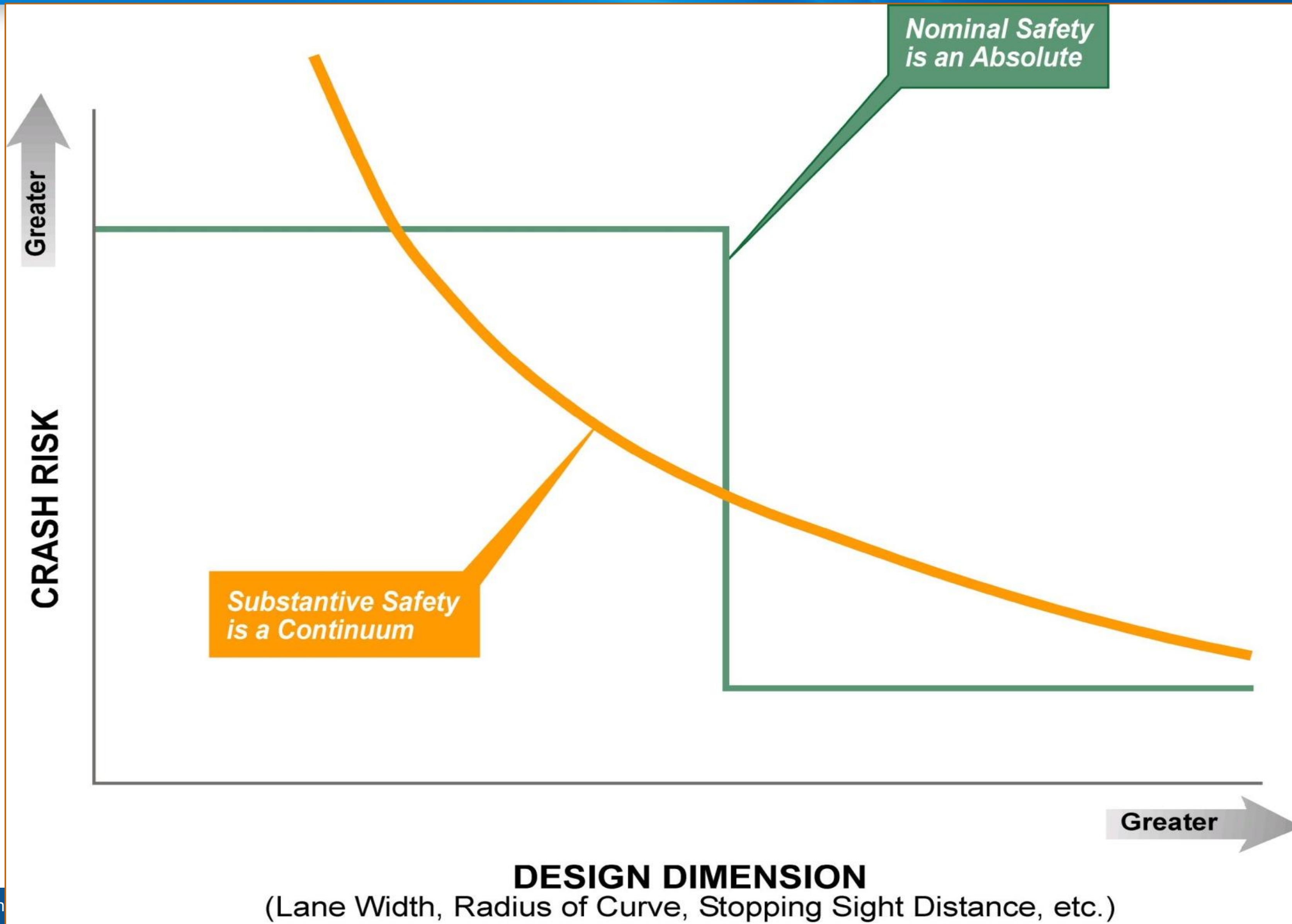
- Legacy is the rural highway system
  - Motor vehicle centric
  - Emphasis on high speed roadway design
- Legacy models and procedures lack basis in science, simplistic in formulation
- Design philosophy employs the concept of conservatism – 'More is better'
- Roadway design references indirectly external controls and processes ('SEE')

Early Research Findings

Alternative Design Processes and Initiatives

Important Insights for the Design Process	Complete Streets	CSS	Perfomance-Based Design	Practical Design	Design Matrix	Safe Systems	Travel Time Reliability	Value Engineering	Designing for 3R	Designing for VLVLR
Roads serve more than just motor vehicles	●	●								
Road design involves many different disciplines	●	●	●			●		●	○	
Context matters and it varies	●	●	○	○	●	○	○	○		●
Performance (operational, safety) is important		○	●	●	●	●	●	○		
Performance may have many dimensions	●	●	●	●	●		●	○	○	
Safety performance should focus on elimination or mitigation of severe crashes			○	○	○	●		○		○
Speed and crash severity are closely linked			●			●				
Existing roads with known problems are different from new roads				●	●				●	○
Traditional design approaches (full application of AASHTO criteria) are believed by professionals to yield suboptimal results	●	●		●	●			○		
Focusing on identifying and addressing the problem(s) should be central to developing design solutions	○	○	●	●	●		○	●	○	
Safety risk and cost-effectiveness are related to traffic volumes			●		●				○	●

The current mental model of designers – 'Design Standards = Safety'



Guiding Principles for an Updated Highway Geometric Design Process

- Fundamental Bases
  - Solutions Should Address Objective, Quantitative Measures of Transportation Performance
  - Explicitly Address All Potential, Legal Road Users
  - Integrate Operational Solutions with Geometric Elements
  - Forward Looking
  - Context Sensitive to the Extent Possible
  - Financially Sustainable
- Social and Public Policy Framework
  - Accountability and Responsibility
  - Legal Framework
  - Support the Financial Sustainability of the Agency's Program
- Necessary Attributes
  - Efficiency
  - Scalability
  - Executable
  - Transparency and Defensibility

Fundamental Bases for Roadway Design

Roadway design projects begin with a stated transportation problem. The purpose of geometric design is to provide the necessary three-dimensional roadway framework to address the problem by providing the appropriate service to the users.

Dimensional and other design standards and criteria are a means to an end. The end is transportation performance, such performance to include mobility, accessibility, safety, and state-of-good repair.

Solving objectively defined transportation problems is the reason for any and every project

Replacement of infrastructure in disrepair

Congestion or traffic operational problems; and accessibility

Safety problems (crash prevention and/or severity mitigation)

Highway design does not occur in a vacuum – the ‘context’ matters… ***and it varies considerably***

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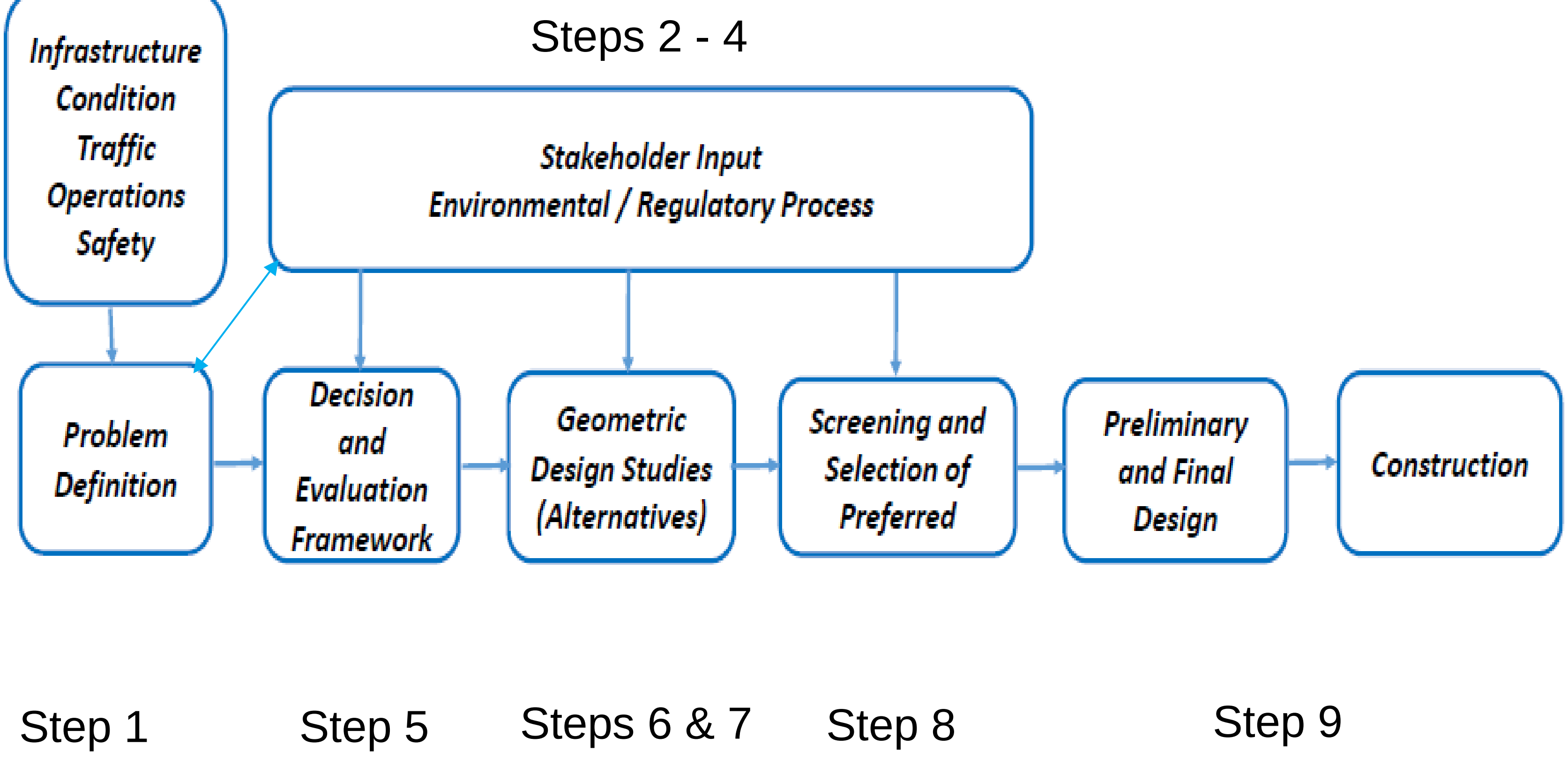
The Design Process Must Be Conducted within the Prevailing Social and Public Policy Framework

The road design process is no longer an independent, wholly technical engineering process. Public allocation of resources, acquisition and use of public rights-of-way, and providing a core value or service to the general public is ‘political’ in the pure sense of the word.

A guiding principle is the explicit recognition of a societal, public policy framework that influences and directs the process and influences the design outcome.

Simplified Geometric Design Process



Recommended Highway Design Process

- Step 1: Define the Transportation Problem or Need
- Step 2: Identify and Charter All Project Stakeholders
- Step 3: Develop the Project Scope
- Step 4: Determine the Project Type and Design Development Parameters
- Step 5: Establish the Project's Context and Geometric Design Framework
  - Framework for Geometric Design Process – New/Reconstruction
  - Develop Project Evaluation Criteria w/in Context Framework
  - Establish Decision-making Roles and responsibilities
  - Determine Basic Geometric Design Control – Design or Target Speed
  - Determine Basic Design Controls
    - Design Traffic Volumes, Design LOS, Road User Attributes

Recommended Highway Design Process

- Step 6: Apply the Appropriate Geometric Design Process and Criteria
- Step 7: Designing the Geometric Alternatives
- Step 8: Design Decision-Making and Documentation
- Step 9: Transitioning to Preliminary and Final Engineering
- Step 10: Agency Operations and Maintenance Database Assembly
- Step 11: Continuous Monitoring and Feedback to Agency Processes and Database

Step 1 -- What is (are) the problem(s)? How should they be defined?

Agency asset management databases, thresholds, policies and program priorities

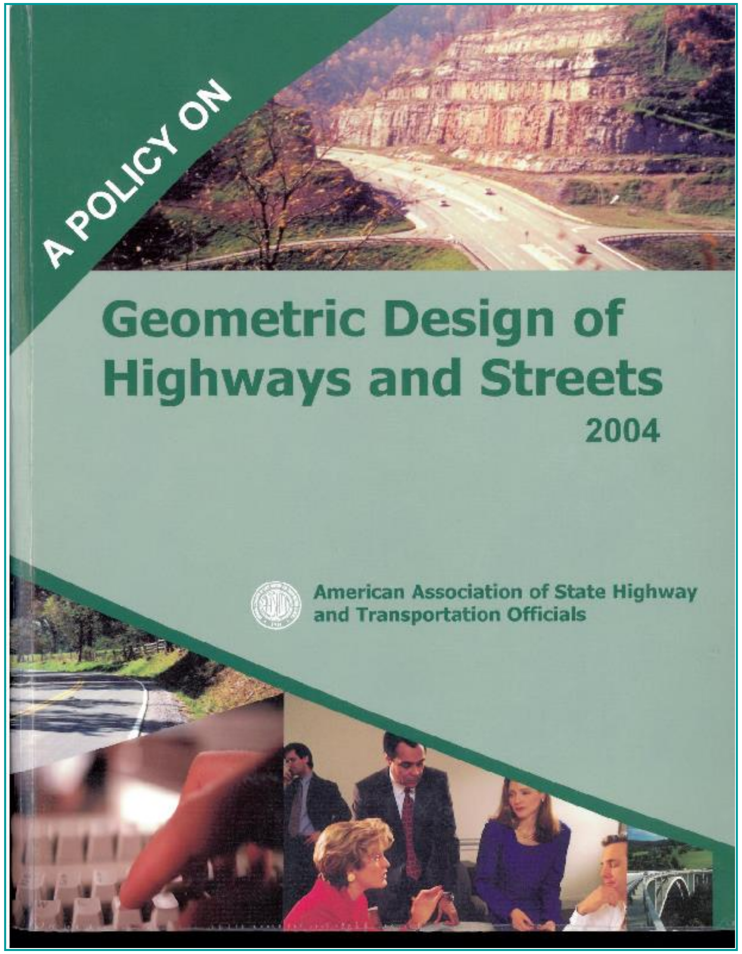
*Level of service, hours of delay, travel time and **travel time value**, speeds, **vehicle operating costs**; thresholds, policies and program priorities*

*Crash frequency and severity by type of crash; **cost or value of fatalities and injuries**; thresholds, policies and program priorities*

Design Standards and Problem Definition

The presence of one or more geometric design features that fail to meet current design criteria is NOT a transportation problem….

It is merely a condition of the context of a reconstruction or 3R project.



Steps 2 and 3 – Identify and Charter all Stakeholders

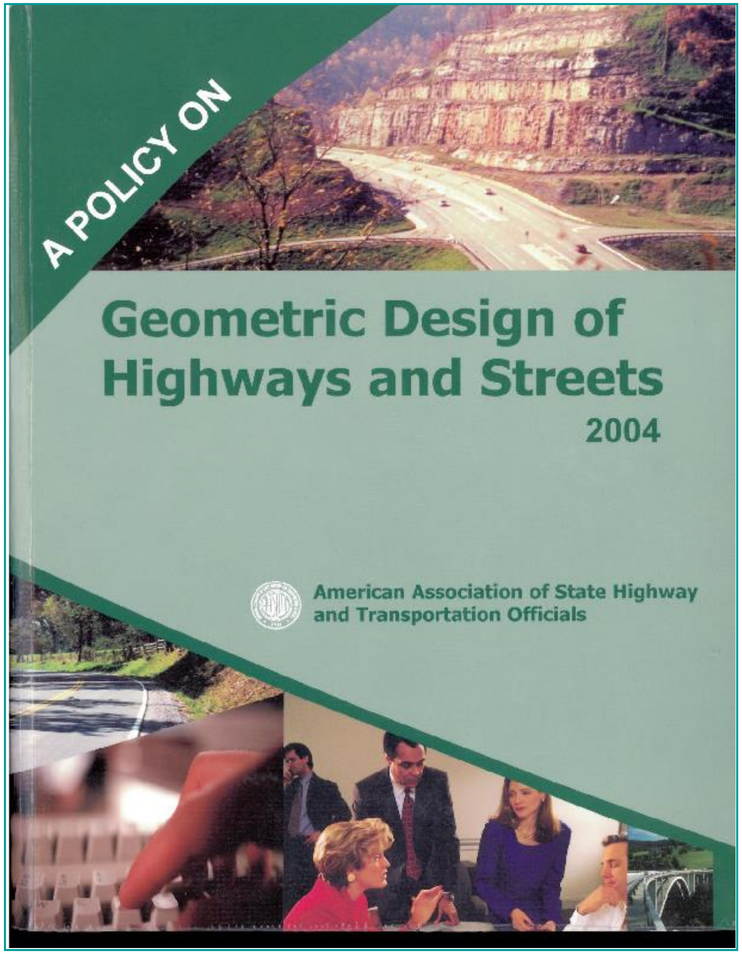
- Internal agency stakeholders
- External governmental stakeholders
- External ‘other’ stakeholders

- Stakeholder Roles
  - Provide data and analysis capabilities
  - Represent specific departmental issues or concerns
  - Are a resource for adhering to applicable regulations and laws
  - Advise in decision
  - Able to veto a choice or decision
  - Participate in/make a decision
  - Provide support for the project’s completion

Step 4 – Determine Project Type

- Major Research Recommendation –

Design policies, processes and values should differ for reconstruction vs. new construction projects (significant change from current policy which treats them as equal or comparable)



Research Recommendation – The design process should treat new construction differently from reconstruction

New Construction*

- *Unknown Safety Performance*
- Unknown Operational Performance
- Available R/W of Sufficient Width
- Minimal Impacts to Adjacent Development
- Construction Costs are Quantity Bases

Reconstruction

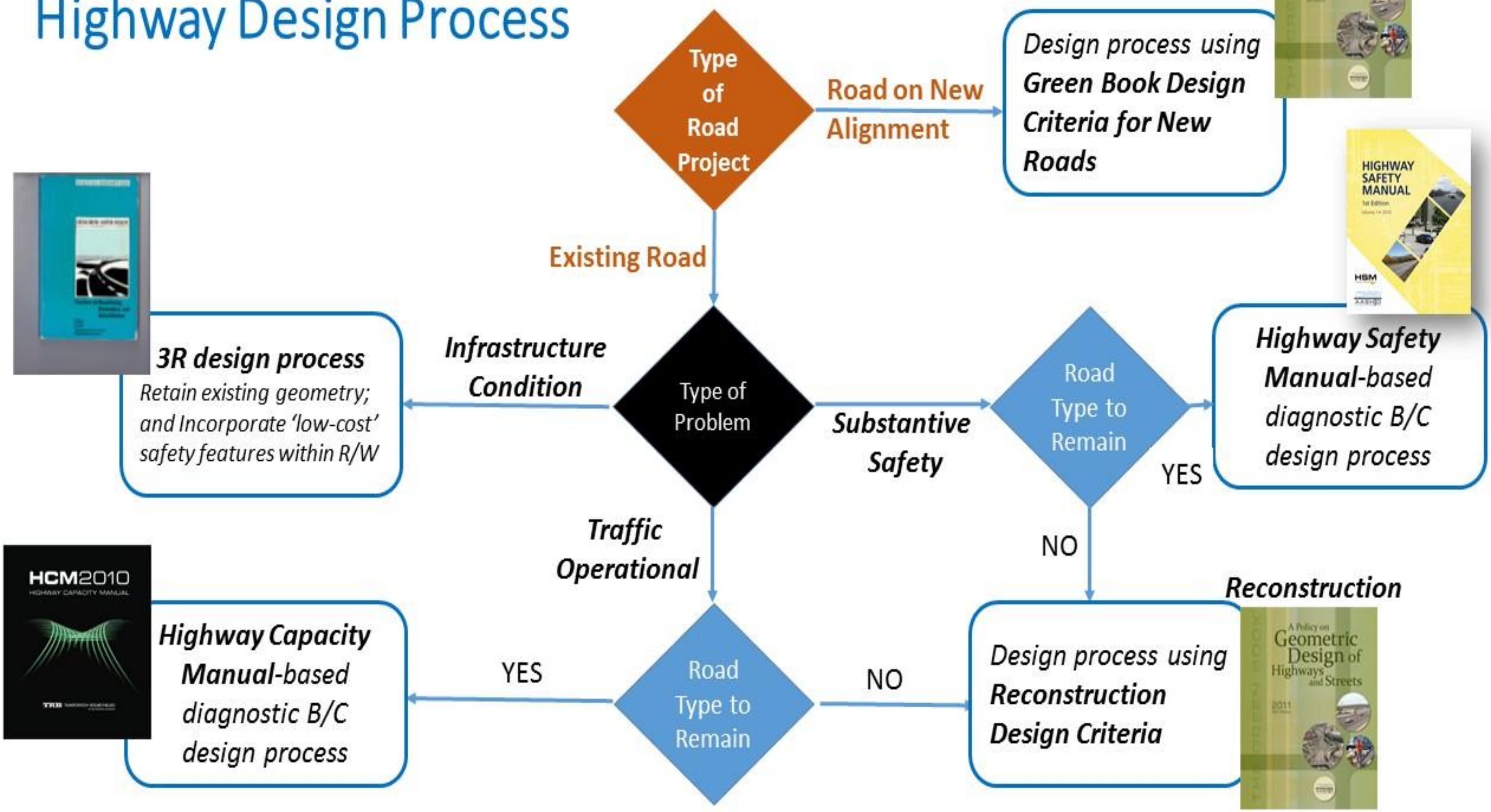
- *Known Crash History*
- Known Operational Performance
- Limited R/W
- Typically Severe Adverse Impacts to Adjacent Development
- Maintenance of Traffic / Local Access Drive Constructability and Cost

*In FY2013 only 5% of Federal obligation funds were spent on new road construction

Project Types and Transportation Problems

Project Type	Transportation Problem			
	Mobility	Access	Safety	State-of-good Repair
New Location	X	X		
3R				X
Reconstruction	X	X	X	X

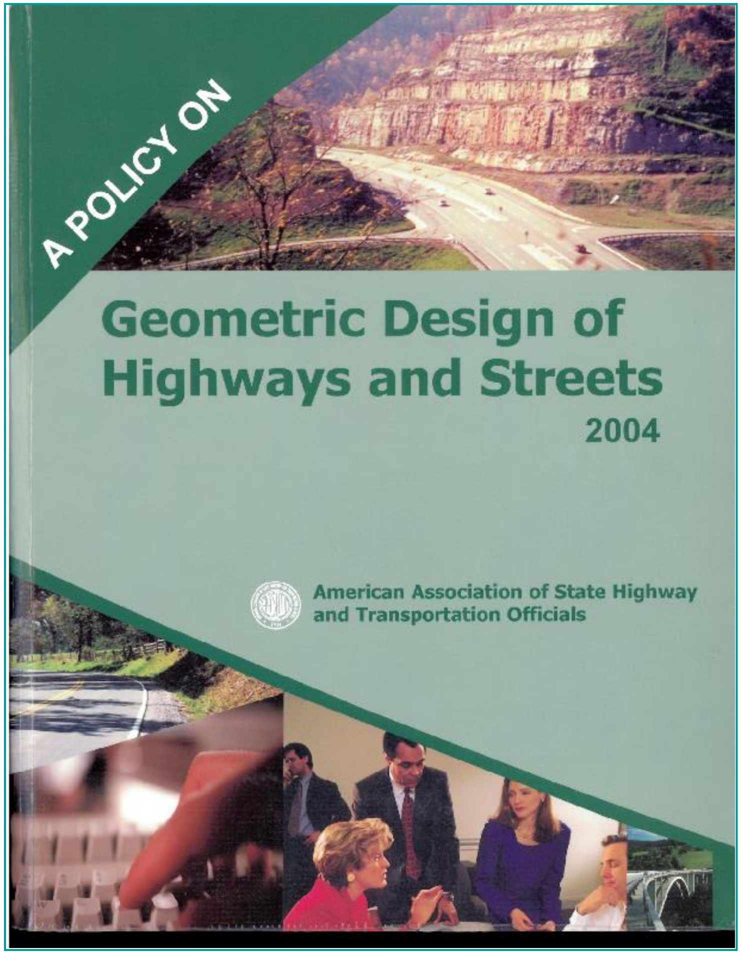
Problem-based Unified Highway Design Process



Step 5 – Establish the Project's Context and Geometric Design Framework

- Reference the Framework for Geometric Design
  - Reconstruction
  - New Construction
  - 3R
- Develop Project Evaluation Criteria w/in Context Framework
- Establish Decision-making Roles and Responsibilities
- Determine Basic Geometric Design Control – Design or Target Speed
- Determine Other Basic Design Controls
  - Design Traffic Volumes
  - Design LOS (or other measures)
  - Road User Attributes

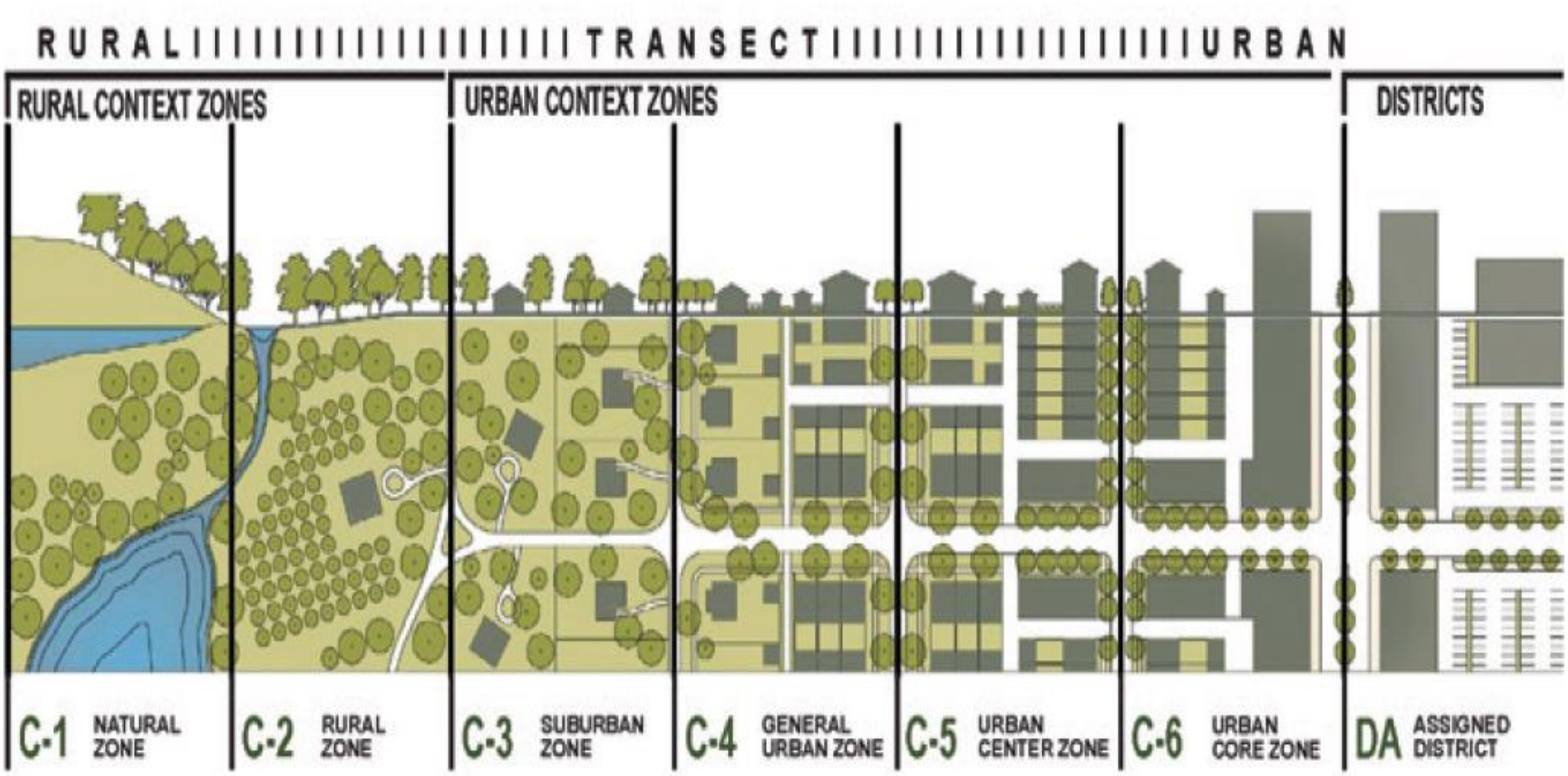
Research Recommendation



- AASHTO's context framework is insufficiently robust or refined
- Context as currently defined:
  - Functional class of road (local, collector, arterial)
  - Terrain (Level, rolling, mountainous)
  - ***Land use (urban, rural)***

The relative importance of non-motorized users in designing highways, roads and streets varies significantly depending on land use.

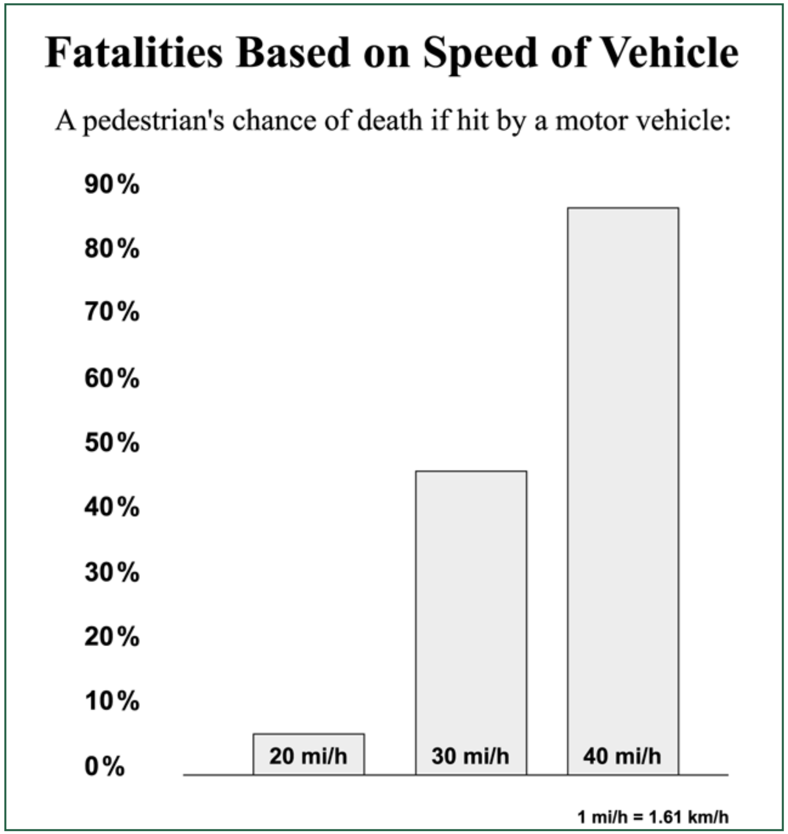
ITE's Roadway Context Zones Help Define the Relative Importance of Designing for non-motorized users



The pedestrian environment demands lower ‘design speeds’

“Design speed is a selected speed used to determine the various geometric design features of the roadway. The assumed design speed should be a logical one with respect to the topography, the adjacent land use, and the functional classification of highway.”

AASHTO Green Book



Serious crash types by location for context zones 1 through 4

**Roadway Segments,
Context Zones 1 & 2,
Highway Safety Manual***

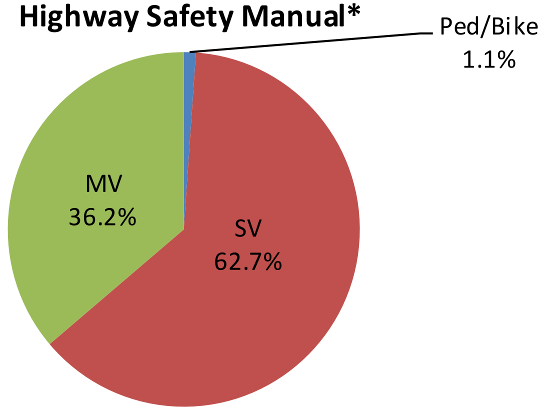


*Table 10-4. Default Distribution by Collision Type for Specific Crash Levels on Rural Two-Lane, Two-Way Roadway Segments (Total Fatal and Injury)

**Intersections,
Context Zones 1 & 2,
Highway Safety Manual***

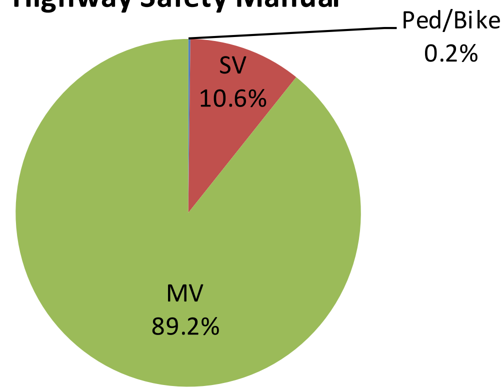
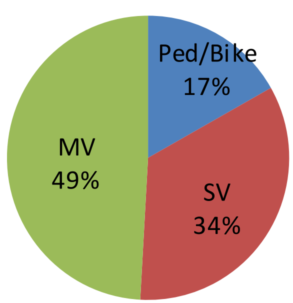


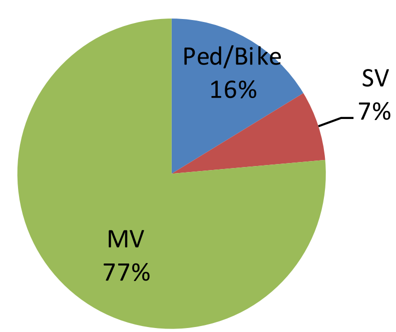
*Table 10-6. Default Distribution for Collision Type and Manner of Collision at Rural, Two-Way, Four-Leg, Stop Controlled Intersections (Total Fatal and Injury)

**Roadway Segments in Cook County (Chicago excluded),
Context Zones 3 & 4**



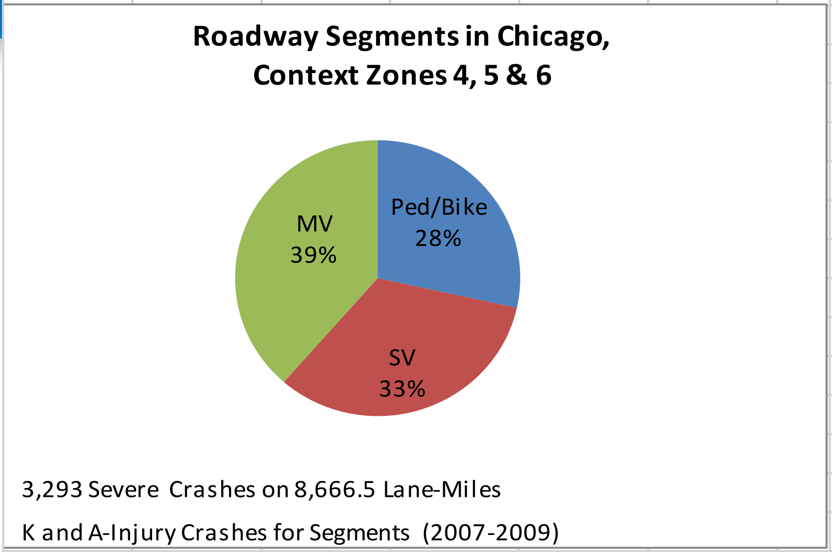
2,659 Severe Crashes on 17,563.5 Lane-Miles
K and A-Injury Crashes for Road Segments (2007-2009)

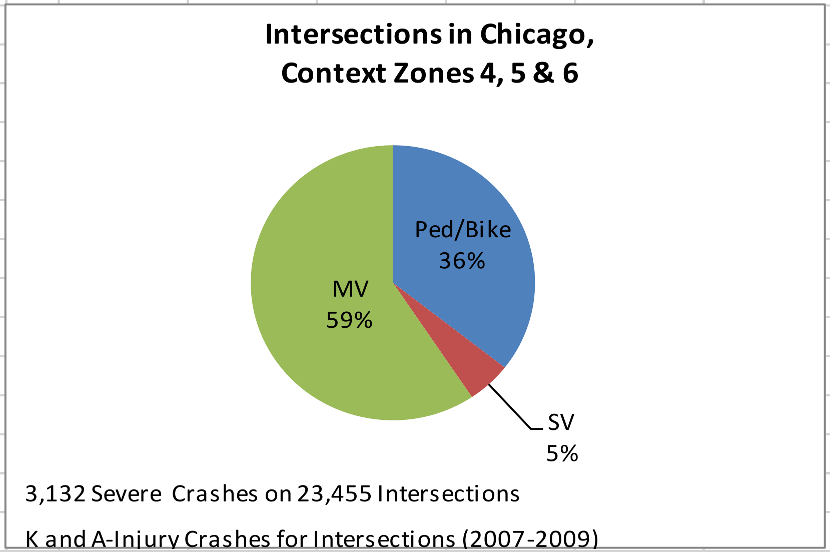
**Intersections in Cook County (Chicago Excluded),
Context Zones 3 & 4**

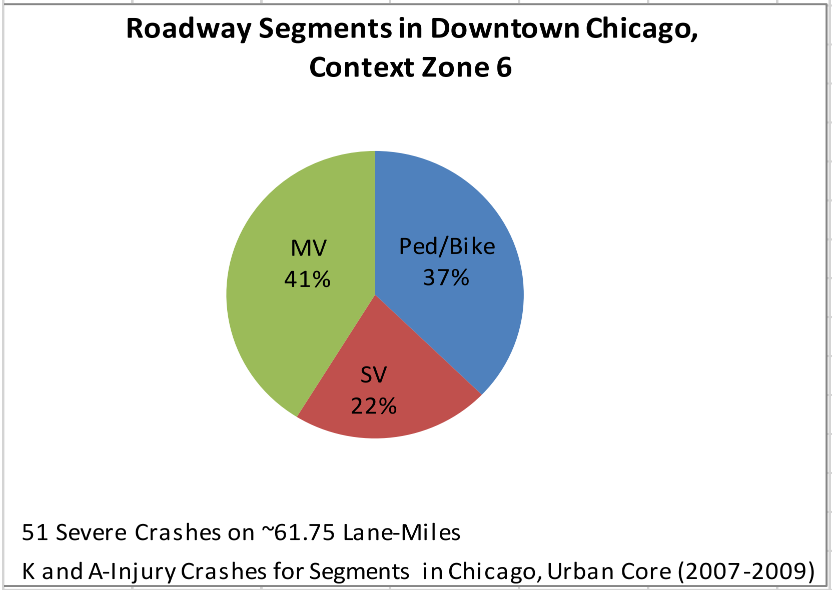


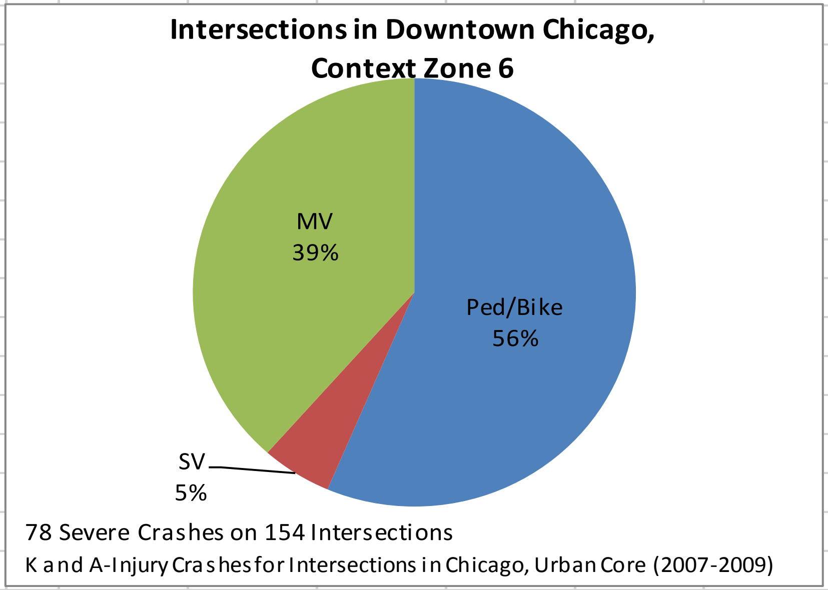
2,735 Severe Crashes on 47,008 Intersections
K and A-Injury Crashes for Intersections (2007-2009)

Serious crash types by location for context zones 5 and 6









Geometric Design Context Framework Comparison

AASHTO

- Functional Classification (3)
- Urban/Rural (Land Use)
- Terrain (3)
- Design Vehicles
- Design Year Traffic
- Project Types (2)
  - New Construction & Reconstruction
  - 3R

Proposed

- Functional Classification (5)
- Land Use / Context Zones (6)
- Design Users
- Design Traffic
  - Design Year
  - Service Life
- Project Types (3)
  - New Construction
  - Reconstruction
  - 3R

Step 5 – The Geometric Design and Decision Framework by Project Type

Reconstruction Projects

- Benefit/cost analysis procedure applying objective metrics and recognizing unique location constraints and issues
- Designers develop and evaluate wide range of cross sectional and alignment alternatives
- Existing ‘non-standard’ design elements are not the problem

New Construction Projects

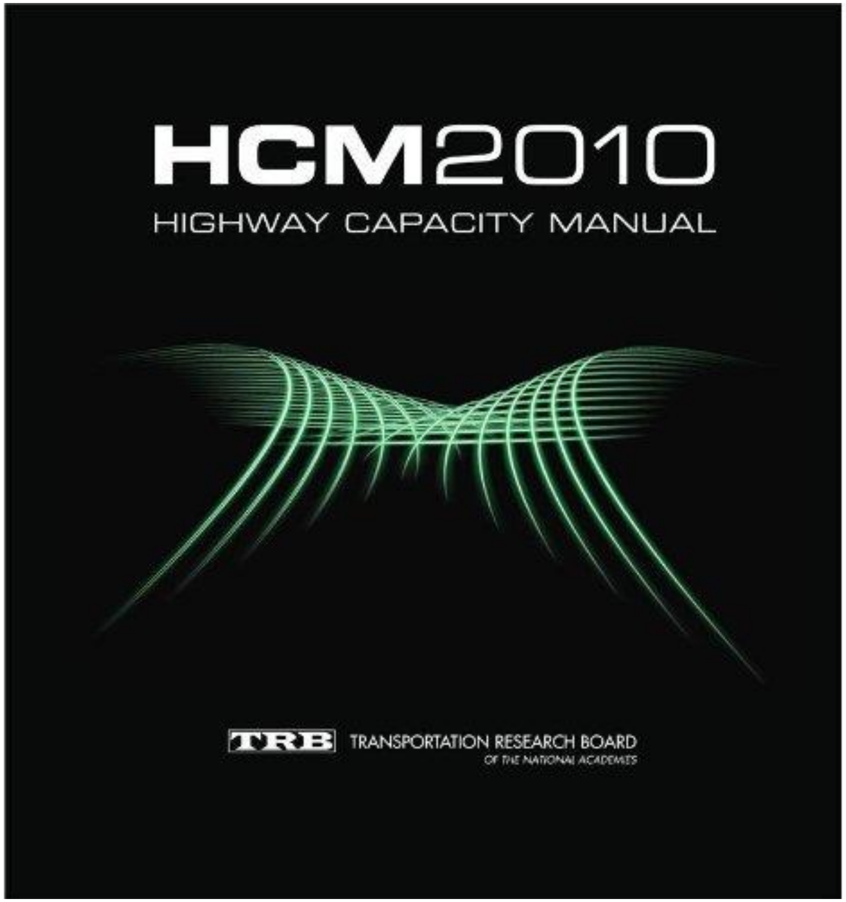
- Green Book geometric criteria applied per current practice…

BUT

- Criteria revised or updated to reflect fundamental principles of cost-effectiveness*

* Discussed in next presentation

Science-based research forms the basis for determining transportation benefits



B/C Process for Reconstructed Roads

- Context is typically unique in meaningful ways
- Existing data support site-specific diagnostics and analyses
  - Simulation can be calibrated from actual field data if needed
  - Empirical Bayes' analysis employs predicted and actual crash history for 'expected' performance
- Process employs site-specific costs
- Appropriate solutions are necessarily tailored to the context, budget and data

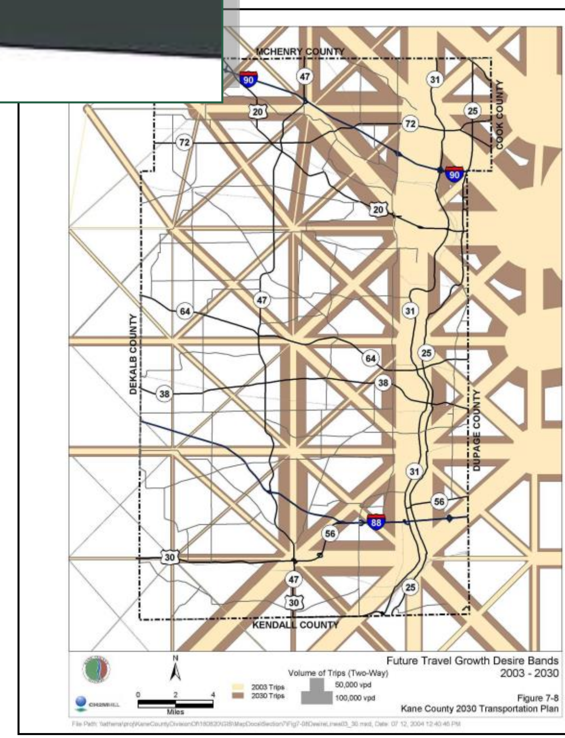
- Benefits
  - Lives saved and injuries reduced
  - Travel time reduced
  - Vehicle operating costs reduced
  - Economic value of land use effects estimated
- Costs
  - Initial construction cost
  - Annual maintenance and operating costs

Transportation agencies would set project definition and decision parameters by policy

- Valuations for fatality and injury savings
- Valuation for travel time
- Interest rates used for discounting costs and benefits
- Threshold B/C ratios for project acceptability
- Service life lengths
- Service life traffic volumes (beyond nominal design year) for project evaluation purposes

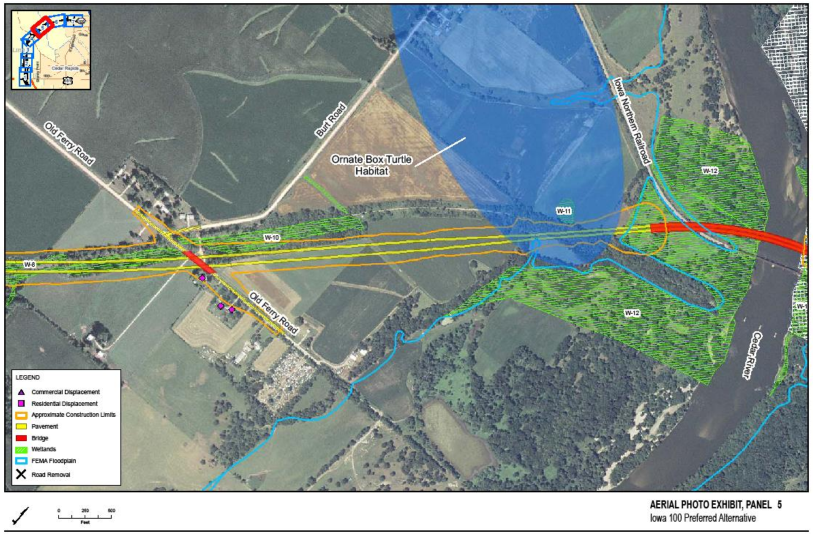
Research Recommendation – Design Year Traffic and Service Life Traffic

- Design Year Traffic is typically 20 to 30 years from study year (per MPO official forecasts)
- Useful life of infrastructure is typically 50 to 100 years
- Transportation benefits accrue to the traveling public well beyond the nominal design year
- Costs are incurred by the owning agency to maintain the project well beyond the nominal design year



Geometric Design Process for Roads on New Alignment

- Dimensional criteria as is currently the case, but with significant changes in their derivation
- Different design models and approaches reflecting full range of context
- Optimization of cross section and alignment based on quantitative tools of performance
  - IHSDM
  - HSM
  - CORSIM/VISSIM (traffic operational simulations)
  - Speed profile analyses



Research Recommendations

- AASHTO geometric design criteria should be revised to be
  - Context sensitive
  - Based on empirical research that demonstrates performance
  - Cost-effective in their derivation and application
- Operational solutions should be fully integrated with presentation of geometric design values

Cost-effective, performance sensitive design criteria

- Incorporate traffic volume (the most direct measure of safety risk)
  - Criteria that currently reflect traffic volume
    - Lane width for rural roads
    - Shoulder width for rural roads
    - Roadside design criteria
  - Criteria that lack traffic volume in their formulation or application
    - Horizontal curvature
    - Stopping sight distance (and vertical curvature)
    - Grade
- Are sensitive to context
  - Criteria that are context-sensitive
    - Lane width
    - Shoulder width
    - Passing sight distance
  - Criteria insensitive to context
    - Stopping sight distance
    - Horizontal curvature
- Reflect proven safety sensitivities (per Highway Safety Manual and other similar research)
  - Roadside design criteria
  - Lane and shoulder widths for rural roads

Updating the Technical Guidance on Geometric Design in the AASHTO Green Book for new projects

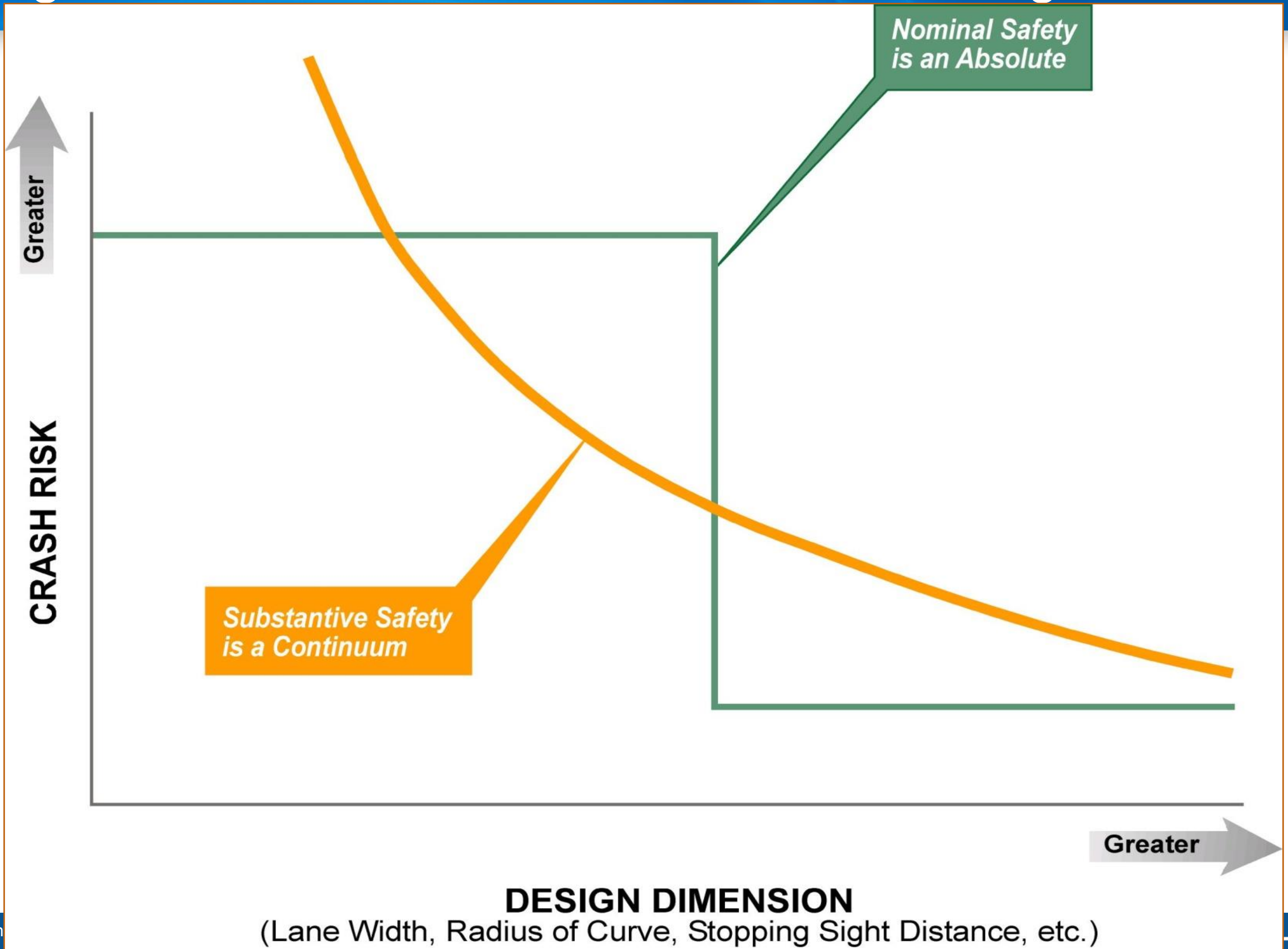
- Context matters – and it varies; particularly with respect to the transportation service for vulnerable road users
- AASHTO dimensional criteria should be based on proven, known measurable performance effects
- Speed is an essential input to the determination of design values and dimensions
- Some AASHTO criteria are not sensitive to key context attributes that are proven influencers of performance and cost-effectiveness; specifically traffic volume and road type
- Some AASHTO criteria are overly simplistic in their formulation, or are based on rational models lacking a proven basis in science
- AASHTO criteria should reflect known interactive safety and operational effects of geometry
- Dimensional guidance should be replaced with direct performance guidance (i.e., dimensions derived from performance metrics)

Paradigm shifts are in order…..

What does it really mean to be 'conservative' as a designer?

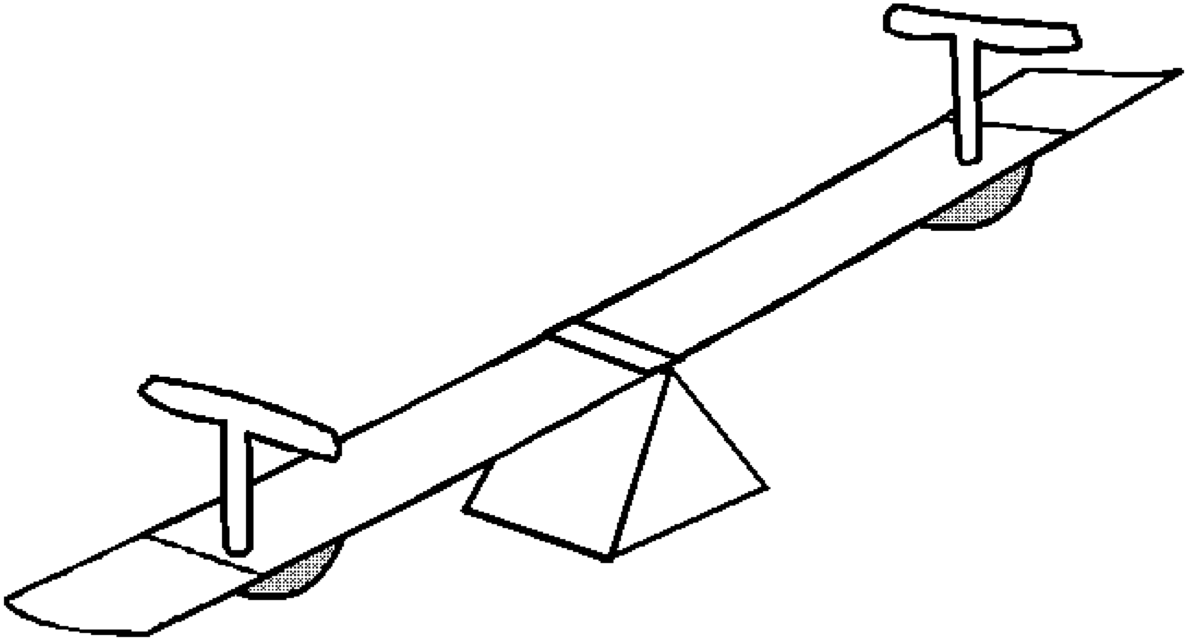
Any expenditure for alignment or cross section features that does not produce a measurable benefit is wasteful. If a policy or design model cannot prove substantive value it should be changed or deleted from guidance.

Design criteria should follow/mirror the orange line



The Future of Geometric Design

Lessened time, effort and expense to complete the design in steps 6 - 9 (per advances in design technology)



Greater effort to engage stakeholders, test and evaluate design effects and apply complex decision processes involving trade-offs (steps 1 – 8)

Transition in skills, knowledge and approach

The 'old model' geometric designer

- Understands basics of vehicle-centric AASHTO models
- Applying the policy and standards to produce a solution that fully meets criteria
- Calculation of alignment
- Balancing of earthwork
- Detailing of construction plans
- Compiling quantities for contract documents

The 'new model' geometric designer

- Engaging multiple stakeholders (some non-technical)
- Proficient in application of tools, models and evaluation methods for operational and safety effects of design (HCM, HSM, IHSDM)
- Always testing multiple alternatives
- Able to design in range of speed and land-use contexts
- Fully knowledgeable in environmental regulations, laws, and processes
- Applying multi-attribute decision models
- Knowledgeable in economic analysis; B/C principles

Discussion